Quantum Physics By Valentine Sherekete

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QUANTUM PHYSICS BY VALENTINE SHEREKETE

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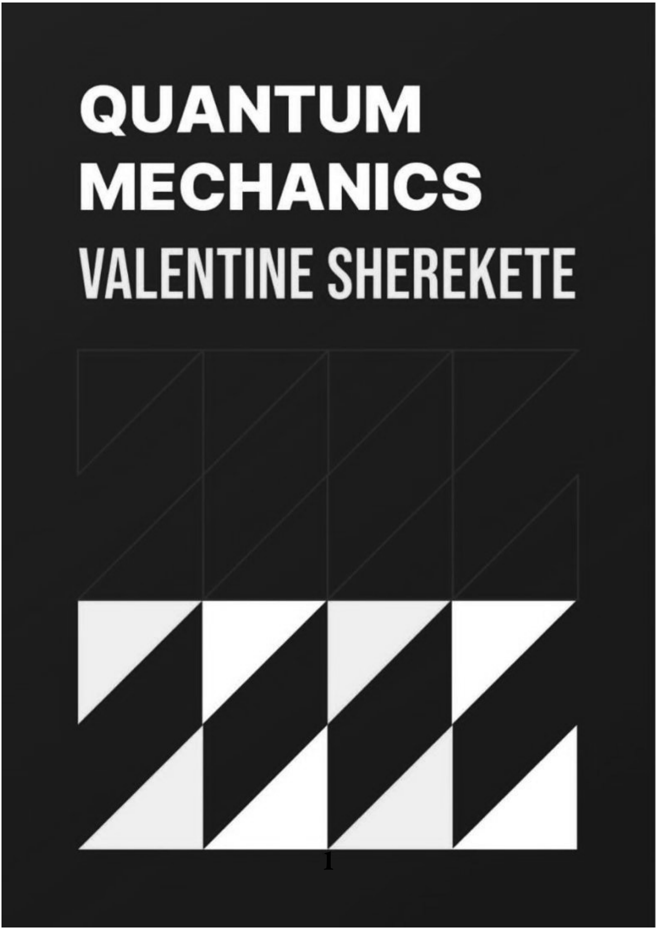
Written by Valentine Sherekete.

To my wonderful family who have given me
lots of support throughout my life



QUANTUM MECHANICS

VALENTINE SHEREKETE

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Dedication

To my wonderful family who have given me lots of support throughout my life.

Foreword

This book is designed to help people to understand Quantum Physics. Its specifically designed for anyone who is interested in learning the mysteries of the universe.

I have described and explained most phenomena using as minimum mathematics as possible. This is to allow anyone to understand the subject without having to re think twice on whether they will understand or not.

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What is Quantum Physics

Most people are told that Quantum Physics is the most difficult subject. This tends to make a majority of people believe in this.

If you take a lens you can zoom small objects and organisms such as plastics debris and ants. This changes our view on the smaller things. For example, looking at ants with our own naked eyes, we could know only a few properties about the organism such as color, speed which it is moving at and the general structure. Now if you take a lens and use it to view the ant, some properties change yet it's still the same ant. An example is you could start seeing its legs and body orientation. This formulation just enlightens you to the changes in observation as we zoom in /out an organism or object.

If you zoom onto any structure of your body for example hands, you will start seeing the skin. Further zooming will start showing the organ in detail while as we even zoom more, we start seeing cells. If we zoom into the cells, we will start seeing cell organelles such as nucleus. If we zoom even more, we will see the atoms making the structures. Zoom into the cells, you will start seeing the sub-atomic particles such as protons, neutrons and electrons. From the level onwards, you are at the atomic level and that when we start seeing most effects of **Quantum Physics in nature**.

Quantum Physics is the study of the smallest objects and how the influence the universe. This gives a rise to so many questions because some of the objects which we study are regarded as negligible in other fields of physics. An example is the photon, which is quanta of light energy or electromagnetic bursts. You can never see a classical scientist considering the effect of light photon on the motion or structure of a classically designed motion experiment.

History of Quantum Physics

Early 1900s:

Scientists were studying the behavior of light and other forms of radiation. They noticed that some of the results didn't make sense according to the laws of classical physics.

1900:

German physicist Max Planck (1858-1947) proposed that energy could only be emitted or absorbed in discrete units, or quanta. This disproved that energy supplied was continuous. This idea, known as Planck's quantum theory, helped to explain the experimental observations. He is considered the father of quantum physics.

1905:

Albert Einstein (1879-1955):

Swiss-German physicist who won the Nobel Prize in Physics in 1921 for his work on the photoelectric effect. He also made significant contributions to quantum mechanics, including the theory of relativity.

1913:

Danish physicist Niels Bohr (1885-1962) proposed a model of the atom that explained how electrons could orbit the nucleus without radiating energy. His model was based on Planck's idea of quanta.

1920s:

Austrian physicist Erwin Schrödinger (1887-1961) developed a wave theory of matter that showed that particles could have wave-like properties. He provided evidence for the atomic model which Niels Bohr had proposed based on laboratory evidence. He then pioneered with the German physicists Werner Heisenberg and Max Born developed to mathematical framework of quantum mechanics, which provides a more complete description of the behavior of matter and energy at the atomic and subatomic level. He published his famous Schrödinger equation in 1926.

1925:

German physicists Werner Heisenberg (1901-1976) and Max Born (1882-1970) developed matrix mechanics, a mathematical formulation of quantum mechanics.

Werner Heisenberg:

He developed matrix mechanics, another mathematical formulation of quantum mechanics.

Max Born:

He developed the probabilistic interpretation of quantum mechanics.

1926:

Schrödinger developed wave mechanics, a different mathematical formulation of quantum mechanics.

1927:

Louis de Broglie proposes the wave-particle duality of matter. He worked to show that waves such as light had wave properties.

1930s:

Quantum mechanics was used to explain a wide range of phenomena, including the photoelectric effect, the Compton effect, and the hydrogen atom spectrum.

1932:

Paul Dirac develops quantum electrodynamics, a theory that combines quantum mechanics and special relativity.

1940s:

Quantum mechanics was applied to the development of nuclear weapons and nuclear power.

1957:

Chen Ning Yang and Tsung-Dao Lee discover parity violation, a violation of one of the fundamental principles of classical physics.

1964:

Murray Gell-Mann and George Zweig propose the quark model of elementary particles.

1995:

Quantum computing is first demonstrated.

1950s-present:

Quantum mechanics has been used to develop new technologies, such as lasers and transistors

Wave-functions

A function is sort of a process which you feed with some input and you except a result. Functions are used in mathematics and there are many examples such as trigonometric, algebraic and Ramanujan zeta functions. Functions makes mathematics more colorful and are also applied in physics. They are sort of a tool which you can feed something waiting for a transformation. Consider when you are at home any you put some dough into the oven then the product is hot bread. In this view, the oven is the function while the dough is the input and the bread is the output.

A wave-function is a mathematical function that describes the possible states which the quantum system could have. An example is the possible states of an electron like spin, position and momentum. This wave-function is not like a real wave but it's just a way which Quantum Physicists use to describe what a quantum particle is and its properties. Wave-functions are constantly changing and evolving, but they won't collapse into a single state until a measurement is performed.

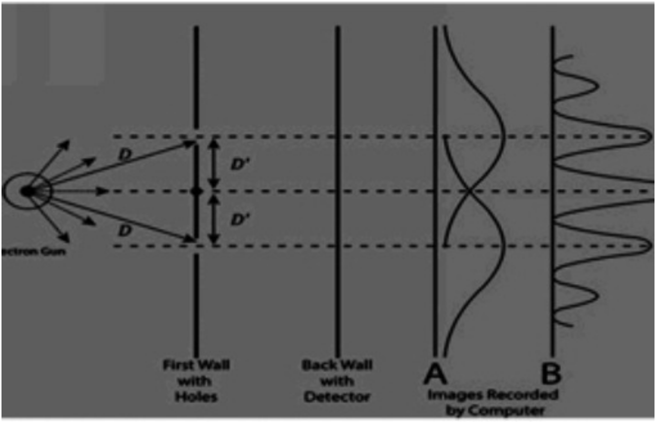
The process which happens during measurement is called wave-function collapse.

Analogy

At a weather forecast station there is a possibility of something happening or not. They then use probability to predict what is likely to happen. Most people blame the people working at weather stations and climatologists when what they predicted doesn't come to happen. But it should be noted that a probability of physical occurrence of something is rarely certain. It only has a certain degree of occurrence and the remaining part is the probability of the event not happening.

Think of a wave-function as a weather forecast for a quantum system. Wave-function will tell you what possible states of the system are, but doesn't tell the actual/ current state which the system is in. The wave-function is constantly changing, just like a weather forecast. But unlike the weather forecast, the wave-function is never one hundred percent certain, and it can only tell you the probability of different states. If and only if the system is measured does the wave-function collapse into a single state, like a rainstorm actually happening.

Double slit Experiment



In this experiment light is passed through two slits and on the other side of the slits is the screen.

Imagine passing having so many balls and then you are to put a wall which have two holes or any two areas left otherwise the rest is a barrier. You then put a space behind the screen such that it records every space where the ball lands. An example is using a white screen then kicking a ball with ink. When this ball reaches the screen, it will cause the ink to color the screen thus serving as a record. Repeating this experiment many times, you will start to see two patterns developing on the screen. This is what we expect whenever we pass a particle though the double slit. This is just because any particles are the same. When we used the ball in our analogy, it was just to make sure you easily understand the example. Also for the detection at the screen and the statistics, you can use what so ever method.

If you are to start kicking the ball through this ball through the wall consider it in the smallest world (the quantum world) it will be the same as shooting some circular particles such as muons, quarks or electrons. These particles are believed to be particles so one would expect to see the same observations as in the given ball analogy. In mathematics they call it scaling.

Concept of Scale

The concept of scale is the same as when you are to draw your cat in your book. Provided that you are a talented artist then you would draw a picture which looks like your real cat. Now your real cat is obviously bigger than what is in your piece of paper. The say that the drawn picture is drawn to scale. And maybe the eyes in the picture will be 5 times smaller than the real image. If the picture is to look in the same way as the original cat, then everything else should be drawn 5 times smaller than the real cat.

In mathematical terms that is the concept of scale. It even applies to you whenever you are taken a photography by someone of even a selfie. That image is not the real you but it's how you look while scaled to fit on the piece of paper. This concept is applied when solving any problem because it's not most times when we use the correct presentation of something. Designers use it when they are planning on a project. It's also used here in quantum physics. We always imagine things as we see them, so maybe instead of speaking of an experiment that uses electrons, we could use balls so that we easily understand the properties we will be trying to acquire knowledge about.

If the experiment is properly done, an interference pattern appears on the screen. These observations are observed in light is behaving as a wave. Now if we are to try and do the experiment while observing which slit the light particle(photon) went through then the interference pattern will disappear. The outcomes imply that light behaves as a wave and when being observed it will change its behavior.

Wave Particle Duality

It was first demonstrated by Louis de Broglie in the 1920s and it was later confirmed by other experiments.

Experiments such as double slit experiment provided evidence for the wave nature of light photons. As the years passed some experiments also began to show the particulate nature of light. An example is the photoelectric effect which was explained by Albert Einstein. Louis de Broglie explained how particles can behave as both waves and particles, depending on how they are observed.

Heisenberg Uncertainty Principle

This is a consequence of the wave particle duality. It proposed by Werner Heisenberg in 1927. It states that we can never know both the momentum and position of any particle at the same time with perfect accuracy. The more accurate we can measure the position of any particle is the less accurately we can measure its momentum. The more we can measure the momentum of a particle is the less we can accurately measure its position. This problem is caused by the fact that the art of measuring a particle changes its state thus we can never know both of these properties for any particle at the same time with a perfect accuracy.

A particle can behave as a wave. So when we measure the particle's position, then we are collapsing its wave-function and this changes its momentum. Conversely measuring the particle's momentum affects its position. Now, the more accurately we measure one property is the more we change the other property.

Microscopic Thought Experiment

This experiment is to color the picture of the Heisenberg uncertainty principle in your mind.

In this experiment, imagine a hypothetical microscope that uses a single photon to image an object. In this case, the photon must collide with the object in order to create the image. Now since the photon has momentum, when collision occurs, this will change the position of the object. As a result, this will cause blurring to the image.

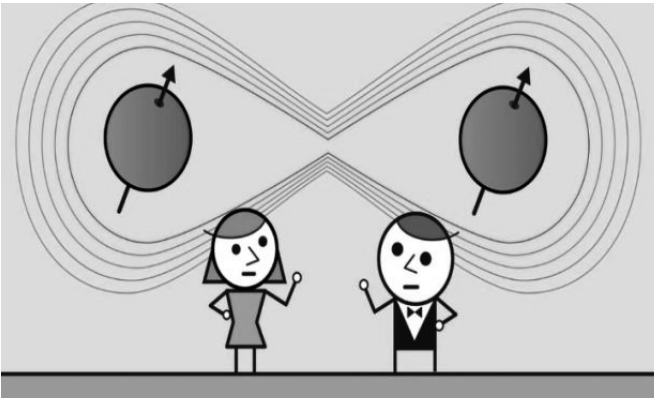
This is a consequence of the Heisenberg uncertainty principle.

Quantum Zeno Effect

This is an effect when the state of a quantum system is measured more frequently and as a result its likely not to change its state further.

Imagine having an unstable particle which is about to decay in the next 5 seconds. Now if the particle is measured every second, that particle will not decay because the measurement then ‘freezes’ its state. Many experiments have confirmed this effect within quantum systems.

Quantum Entanglement



Quantum Entanglement

This is the phenomenon when two particles get "entangled" meaning that they are linked together and share properties despite being separated. If we have two entangled particles we could use measurement of one particle to know properties of the other. An example is with to entangled electrons, once we measured one electron to be a spin-up then instantly the spin of the other electron will be an up-spin, even if they are separated by billions of light years apart.

EPR (The criticism of Quantum Physics)

This EPR paradox is a thought experiment that was proposed in 1935.It was pioneered by Albert Einstein, Podolsky and Rosen. Hence its name EPR. The argument was that Quantum Mechanics was not complete. Einstein, Podolsky and Rosen thought that quantum mechanics could not explain many things like the existence of hidden variables which influenced the world at Quantum level. The three scientists proposed a thought experiment involving two entangled particles which are then separated a very large distance. Quantum mechanics then says it is not possible to know the values of some properties which the particle possesses such as position and spin until they are measured. Now in contrary, the EPR paradox suggests that the two entangled particles have a definite value of the property even before they are measured. This opposes the suggestions made by the Quantum explanation of the entangled particles.

First experimental observation of entanglement

Alain Aspect and his colleagues were enthusiastic about Quantum Mechanics so they performed an experiment to confirm quantum entanglement. In the experiment they used two laser beams to produce a pair of entangled photons. Each of the two entangled photon beams were further split into two parts with each part of the four beams being send to four different detectors. After the polarization of the photons were measured, they were correlated despite being separated by a large distance. As a result, this confirmed QUANTUM ENTANGLEMENT

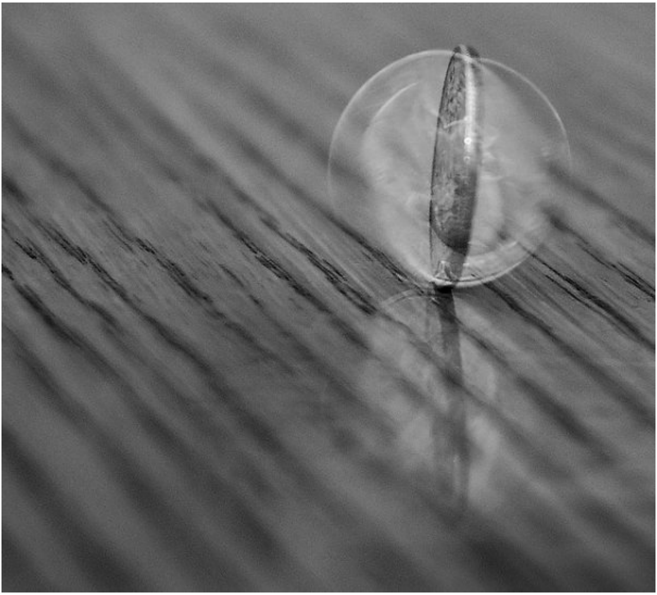
Bell's inequality and hidden variables

In 1964, John Bell formulated a mathematical inequality in order to verify the existence of local hidden variables. Hidden variables are a set of hypothetical properties that influence the outcome of measurement but they are never directly observed. Bell's inequality states that the correlations between the measurement of a quantum system's properties cannot be greater than a certain value provided that hidden variables are influencing those correlations. If experiments match with this inequality, then hidden variable concept could exist but experiment violated this inequality which means that hidden variables cannot explain the results of quantum mechanics.

The Schrodinger's cat Thought Experiment.

For this experiment imagine placing a cat inside of a box which you have no way of determining what is inside. This maybe mean its sound proof, motion proof and prevents someone outside from seeing what is inside. An example is the banking vault boxes. So when you put the cat, you also put a radioactive switch with a poison. What happens is that the radioactive switch has a sample of nuclei which have a fifty percent chance of decaying. When this sample decays it will then split the poison and kill the cat. So if we are to set up this experiment then there is no way to claim whether the cat is either dead or alive. This is to illustrate the idea of superposition as you could say its dead and alive at the same time.

Chigoza (Coin Analogy)



Imagine that you have two coins, and you flip them both at the same time. If one coin lands head up, the other coin must land tails up. This is because the two coins are linked together. They share the same fate.

The quantum entanglement is similar to this, but on a much smaller scale. Instead of using coins, we're talking about some particles like electrons. And instead of flipping them, we're about their spin.

Box Analogue

Imagine when you have two boxes, and then you put one shoe in each box from one pair. You then seal these two boxes and send them to two different people, who are far apart.

Now, you open one of the boxes and find that the shoe is a right foot shoe. You can instantly deduce that the shoe in the other box must be a left foot shoe, even though you haven't opened that box yet.

Imagine you have two magic boxes. When you put an electron in one box, the electron in the other box will change to the same spin. No matter how far apart the boxes are, the electrons will always be linked together.

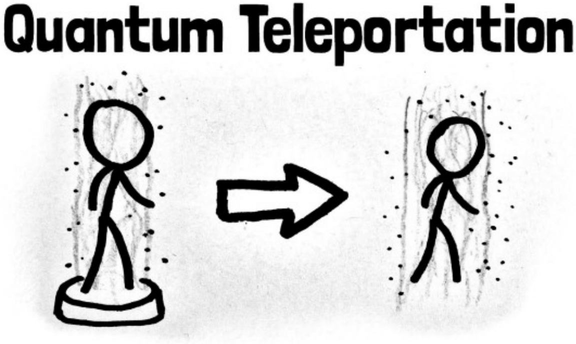
QUANTUM CORRELATIONS

This is a measure of the degree to which the properties of quantum system are correlated regardless of their separation. An example is how to two entangles photons still have correlated polarization effects even when they are separated longer distances. The correlation effect is due to the particles being part of the same system before they are separated and measured. The violation of the Bell's inequality in experiments is a direct result of Quantum correlation

ENTANGLEMENT SWAPPING

This is when two pairs of entangled photons are combined to create a new pair of entangled photons. The new pair created is entangled with both the original pairs even if they might not have been directly linked. Entanglement swapping results because of Quantum correlations, which allows for the sharing of information between particles that never interacted.

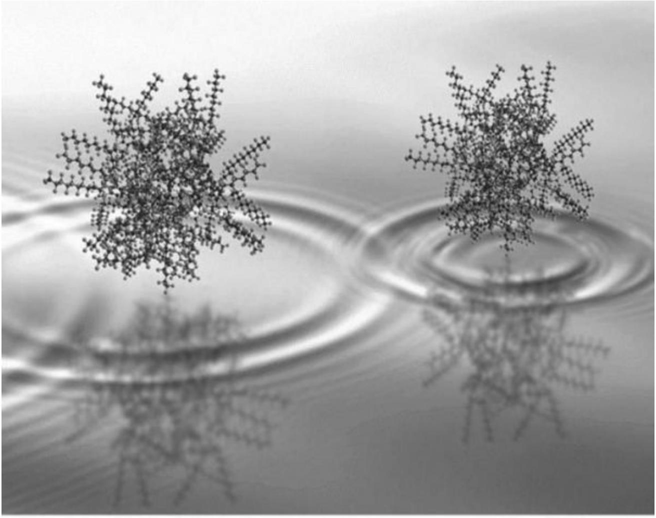
QUANTUM TELEPORTATION



In Quantum teleportation the quantum state of a particle is "teleportation" from one location to another without actually moving the particle Quantum entanglement which makes it possible to share information to be shared between separated particles is also responsible for this.

In order to teleport a quantum state, two particles are entangled and a third is in the same state as the first particle. The first and third particles are identical but not entangled. If we measure the quantum states of the first and second particles that of the third particle is also changed to match the state of the first particle. This is called **QUANTUM TELEPORTATION** because the state of the first particle has been “teleported” to the third particle. This teleportation happens instantly.

Quantum States and Superposition

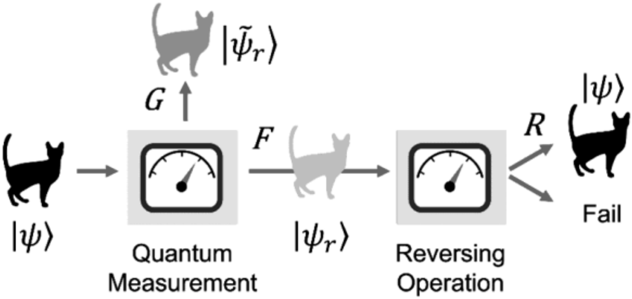


In classical world, we mostly have only two states which is either one state of the opposite state. An example is when you spin a coin, you will get either a head or a tail but no experiment will give you a head and a tail at the same time. Now in the quantum world, a system can exist in both states at the same time.

Superposition is the phenomenon when the quantum state of a system is a combination of two or more quantum states

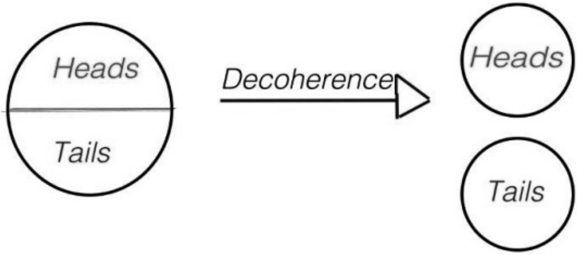
An electron can either spin up or spin down in the classical world. This is very different to the quantum world where the same electron can be both spin up and spin down at the same time. This is the superposition. This is not just a theoretical concept but experiments have been done to confirm it.

Quantum Measurement


$|\tilde{\psi}_r\rangle$
G
$|\psi\rangle$
R
F
Fail
$|\psi\rangle$
Quantum Measurement
$|\psi_r\rangle$
Reversing Operation

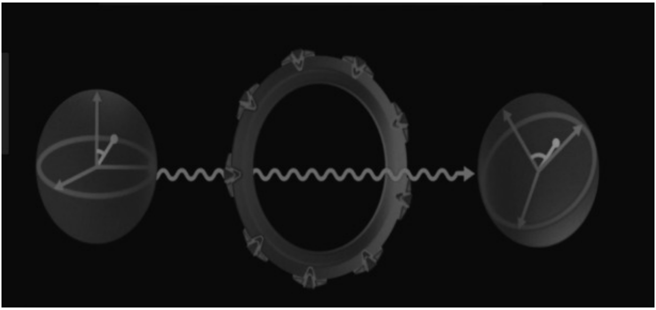
This is the process when someone measures the state of a quantum system. Measurement collapses the superposition of a quantum system into a single state. For example, when someone measures the spin of an electron, they will observe either a spin up or a spin down. It is more important to note that a system loses is superposition due to measurement. Once superposition is lost, it can never be regained again.

Quantum Decoherence



Decoherence is the process of a quantum system losing its superposition state. This happens when a quantum system interacts with the environment. An example is when someone spins a coin in air, it will be in superposition of states until the moment it lands on some environment like a table. The process of landing makes the system lose its superposition in a similar way as quantum systems witness decoherence. Decoherence causes error in the quantum calculations in quantum computing.

How Quantum Engineers are fighting decoherence.



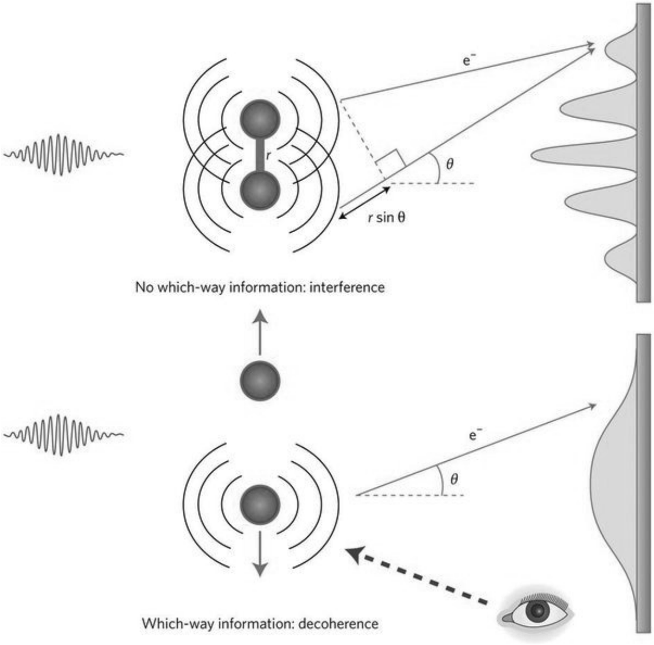
Quantum engineers are trying to reduce de-coherence using some methods such as quantum error correction and quantum error avoidance.

In quantum error correction, an extra qubit is added to the system and this helps in correcting errors due to decoherence.

Quantum error avoidance involves designing quantum algorithms that are less sensitive to decoherence. All these methods are made in order to minimize decoherence.

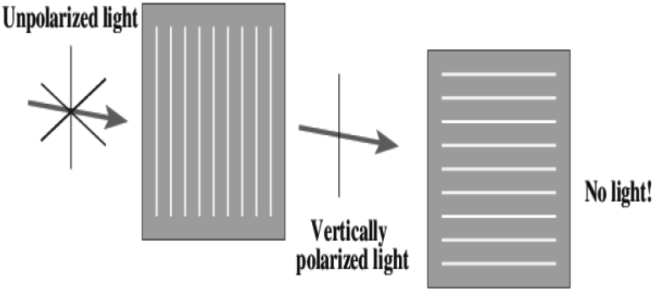
Real-life examples of quantum superposition:

Double Slit Experiment


e⁻
r
θ
r sin θ
No which-way information: interference
e⁻
θ
Which-way information: decoherence

Electrons in a double-slit experiment are in a superposition of being both in the slits and not in the slits at the same time. This is what causes the interference pattern that is observed in the experiment.

Polarization

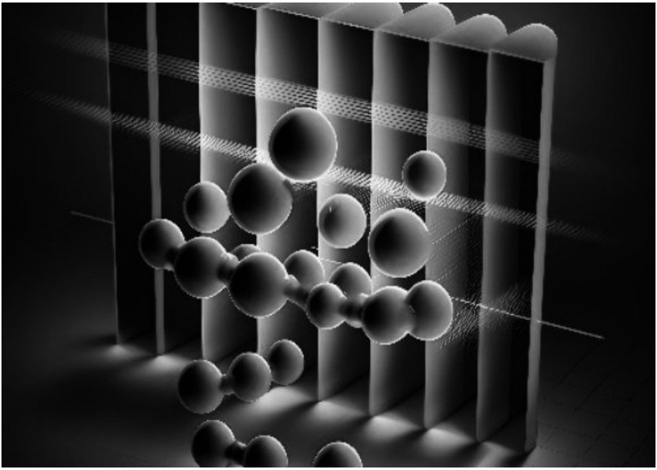


Photons can be in a superposition of being both polarized in a vertical direction and polarized in a horizontal direction at the same time. This is used in quantum cryptography to create secure communication channels.

Atomic Topology

Atoms can be in a superposition of being both in one place and in another place at the same time. This is used in quantum tunneling, which allows electrons to pass through barriers that they would not be able to pass through classically.

Quantum Sensing



This is a technology which uses quantum properties such as entanglement to create very sensitive sensors. Quantum sensors are very powerful and they can detect very tiny changes in magnetic fields, electric fields and gravitational fields. This opens a whole new range of possible applications in many fields such as medical imaging, navigation and to another extend the detection of dark matter.

Medical Imaging

ziehm imaging
Ziehm Quantum

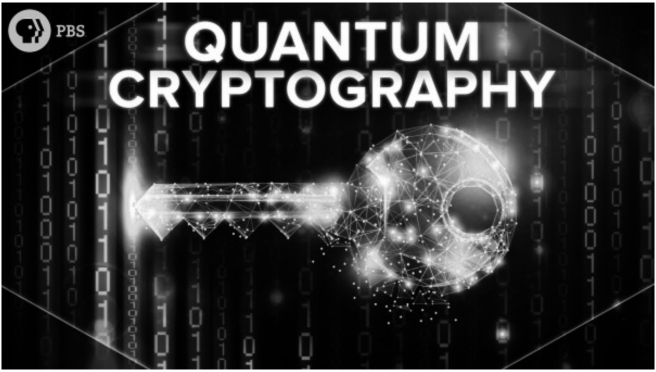
Quantum sensors can detect very small changes in magnetic fields caused by body organs and tissues. This produces highly precise images of the body. This makes us able to detect tumors and monitor the progression of disease spread or treatment. They can be used to measure the electrical activities in the heart and for creation of brain-computer interfaces (BCIs). The brain-computer interfaces are devices which allow people to control robotic and electronic devices using their thoughts only. BCIs have a very huge potential in applied technology to help people living with disabilities. These technologies help in communication and gives the power to control devices. It is believed that this technology could be used to treat some neurological diseases such as epilepsy and Parkinson's disease.

The other application of quantum sensors is in the detection of cancer cells. Cancer cells have electrical properties which are different to the health cells and this is how they are notices using quantum sensors.

Quantum sensors can be used in the self-driving car industry. Thy could be used to detect the real-time position of the vehicle relative to other objects. This is helpful in detecting obstacles and changes in the environment.

Quantum sensors can also be used in the navigation field. They can detect the changes in the earth's magnetic field and thus gives more accurate and precise navigation. They can also detect gravitational waves leading to new discoveries in cosmology and astronomy such as dark matter.

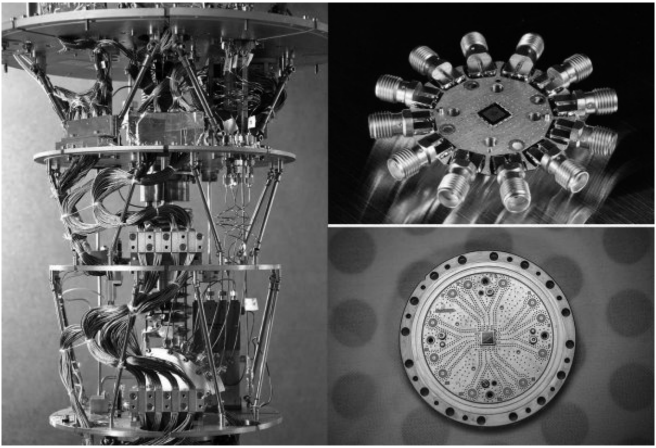
Quantum Cryptography



Quantum cryptography is a way of sending information using quantum properties like superposition and quantum entanglement. The message used in this communication method are encrypted using Quantum Key Distribution (QKD). Quantum cryptography has potential application in secure communication networks which will be used in banking, military, governments, secret services and internet of things (IoT).

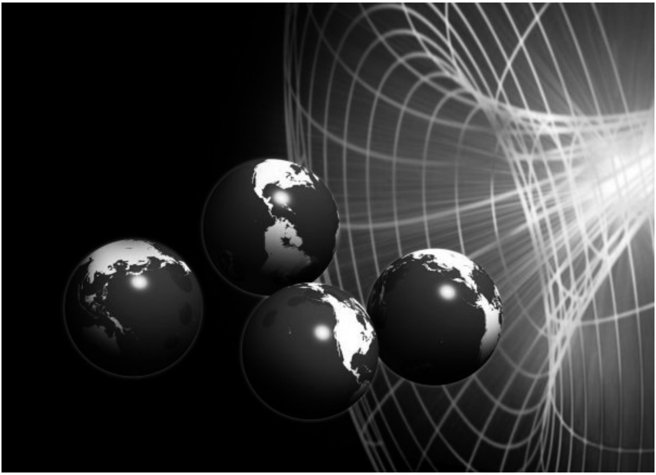
An advantage of quantum cryptography is that it is extremely difficult to hack and this means that its more secured. This method much more secured than the traditional encryption methods which uses classical technology. Even if someone were to intercept a message, then they would not be able to read it without altering the quantum properties of the message, and then the receiver will easily discover that someone else had opened the message.

Quantum hardware



Quantum computers and systems uses quantum bits, qubits which are made from quantum systems like trapped ions or superconducting circuits. These systems are kept at very low temperatures in order to keep functioning properly. One of the biggest challenges which quantum computers witness is developing big systems and hardware since they need to use more qubits. This is because many qubits are required in order to make better systems. On the other side the qubits need to be kept isolated from the environment in order to minimize quantum decoherence. This becomes complicated to achieve if we are using bigger systems.

Many Worlds Interpretation of Quantum Physics



Imagine a tree with many branches. The wave-function is like the branches of a tree, and each branch represents a possible state of the system. When the wave-function collapses, it's like one of the branches being chosen and becoming the "real" state of the system.

Collapse Problem

The collapse problem arises from why and how the wave-function collapses into a single state after being measured

The "Many World's Interpretation", which states that all possible states of the wave-function actually exist in different universes.

Multiverse

The philosophical questions posed by the many world interpretations raises some questions such as the multiverse. The questions are that if we live in a multiverse, then does that our choices and actions matter because every possibility outcome exists in some universe?

In the Many World's Interpretation, measurement is simply decoherence of the quantum system. The wave-function will become entangled with the environment. So this means that in the Many World's Interpretation, measurement doesn't collapse the wave-function, but instead it makes it "real" by making it part of our universe.

Quantum Immortality

This is a derivative of the *Many World's Interpretations*. This simply mean that since all possible outcomes of the wave-function exist in different universes therefore we can never truly die.

But instead our consciousness is simply "shifts" to a new universe when our body dies in this universe.

Quantum immortality raise some difficult philosophical questions such as the nature of personal identity and consciousness.

Functionalism

This school of thought holds that consciousness is simply a function of the brain. According to our view if our consciousness could shift to another universe, it would be the same consciousness since it's just a function of the brain's structure and activity.

Dualism

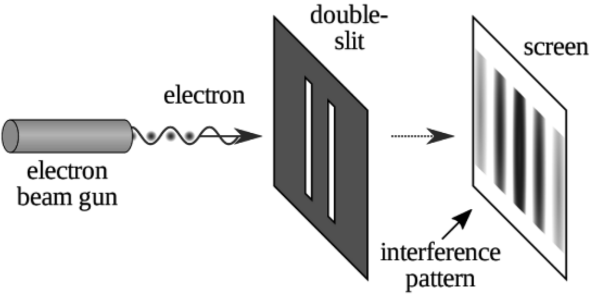
This school of thought holds that consciousness is a non-physical property and exist separately from the physical brain. This view also suggests that if we shift our consciousness to a new world then it would be a different and new consciousness since it's not bound to the physical world.

Personal Identity

Even though we have assumed and agreed that consciousness could shift to a new universe, it also raised the question of whether if the new consciousness is the same person as the original. This is called the "Identity Problem" in philosophy. This problem is solved by the Many Worlds' Interpretation because it implies that every possible outcome of an event will create a new universe. Thus even if our consciousness is shifted to a new universe, it's still the "same" consciousness, just that it is in another different universe. This is called the "**Many World's Interpretation**".

In general, the many worlds interpretations, says the universe is constantly splitting into multiple universes, each with their own unique histories. This means that every possible outcome of every event actually happens in some universe or another.

Copenhagen Interpretation



This perspective explains that a measurement collapses the wave-function into a single state. This interpretation says that before measurement, the object exists in a superposition of multiple state. Once an observation is performed the system then collapses into a single state. This brings some phenomenon such as “Scrod dinger’s cat” thought experiment.

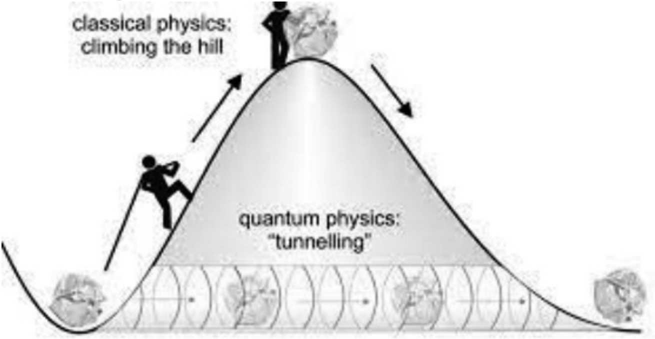
Problem in Double Slit Experiment

(Copenhagen Interpretations Vs Many World's Interpretation)

In the double spit experiment, a light is beamed through two splits from the source to the screen on the other side.

Now the Copenhagen Interpretation says the wave function collapses when we measure which split the particles pass through both splits, but in different universes. This means in one universe it goes through the left split while in the other universe it goes through the right split. Thus in Many World's Interpretation.

Quantum Tunneling



Quantum Tunneling is the process by which a particle can pass through a barrier that it cannot be able to pass in the classical world. This phenomenon is possible because of the wave properties of quantum particles. In classical world, if a particle approaches a barrier, it will simply collide with it and bounce off. In the quantum world, this particle's wave function could spread out beyond the barrier. As a result, there is a certain probability of existence of the particle on the other side of that barrier. This works even if the particle shouldn't pass the barrier.

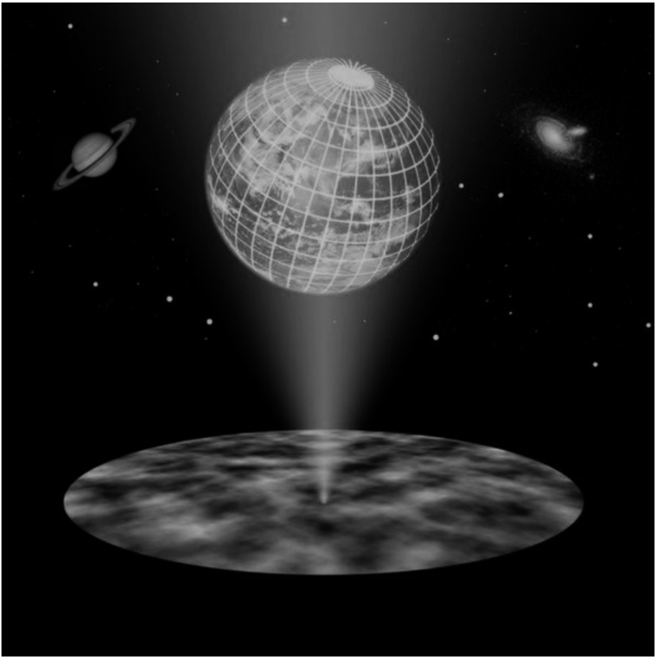
This phenomenon is like rolling a black ball towards a higher hill, then it would appear on the other side without having gone up the hill as expected.

Application of Quantum Tunneling

Quantum Tunneling happens in nuclear fusion processes. This is because the two particles which are involved in the reaction, the protons in the nucleus will repel each other if they are brought near each other and as a result no relation happens. So in order for nuclear fusion reaction to occur, Quantum tunneling first occurs allowing the proton reactants to tunnel into each other without any repulsion. Also the flow of electrons in a transistor relies on quantum tunneling process.

Other scientists are investigating if it's possible to create the "warp drives" which allows faster than light travels. In these technologies quantum Tunneling is the essential theoretical basis.

Holographic Principle.

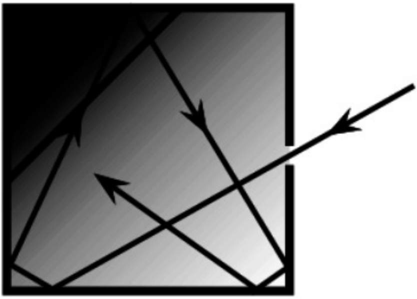


This was first proposed by the physicist Gerard 't Hooft and later expanded by Roger Penrose and Leonard Susskind. It states that the universe is like a hologram where all the information is encoded on the surface of the universe, instead of being in the volume of space inside. This is a part of the broader theory called **'String Theory**.'

String Theory

This is a “theory of everything", and it was made as an attempt to unify all the laws of physics such as the Quantum Mechanics and General and Special Relativity. In the String Theory, the most fundamental building blocks of the universe are tiny vibrating strings. These Strings have different modes of vibration and it's these different vibrations that gives rise to the different particles and forces which exist in the universe. In this theory, there are more than four dimensions of space-time.

Black body radiation and the Ultraviolet Catastrophe



Blackbody Radiation is the electromagnetic radiation emitted by a perfect black body. A black body is any objects which absorbs all the electromagnetic radiation that hits its surface. According to classical physics, the amount of radiation emitted by a black body should continue to increase limitless as the wavelengths becomes shorter and shorter. This leads to an infinite amount of energy being radiated at high frequencies such as the ultraviolet light. However, these classical predictions didn't match the observed results. This became a gap of knowledge in classical physics and served as motivation in the development of Quantum Physics.

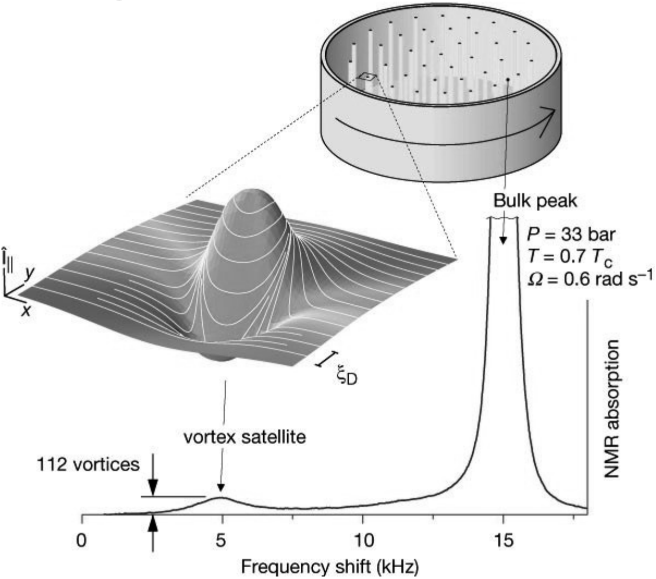
Quantum Physics solved the ultraviolet catastrophe by applying the idea of "quantization." In quantum Mechanics, energy is not continuous but it comes in "quanta." A quantum is the fundamental discrete packet of energy and it's plural is quanta.

Quantization solved the ultraviolet catastrophe, explained the results from double slit experiment and other experiments. It also has quantum physics the name Quantum.

Observer effect

This is the effect when superposition is "collapsed” due to observation or measurements. The observer effect is not about a conscious observer but instead it's about the interaction between the quantum system and its environment. It is during this effect when the superposition collapses into a definite state. It's also the same as the moment you see whether the coin is either up or down after spinning it.

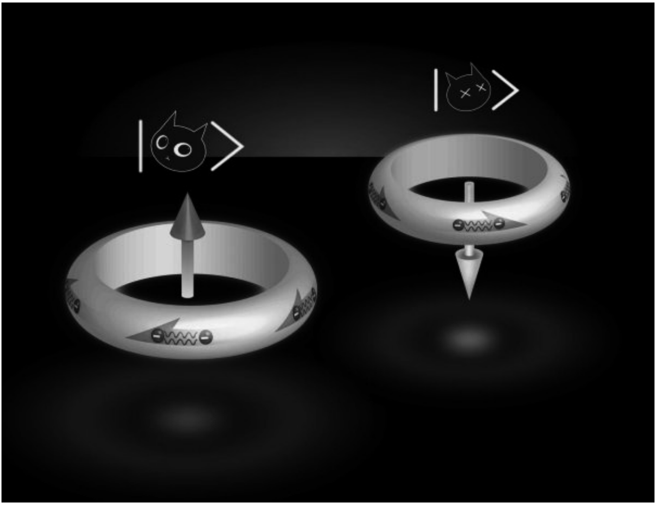
Quantum Superfluids



A superfluid is a liquid that behaves in unexpected and strange ways due to the quantum properties of its particles.

Liquid helium at very low temperatures behaves like a superfluid. Superfluids have zero viscosity meaning that there is no resistance to that flow. They also gave zero entropy meaning there is no disorder. These fluids have some weird properties like flowing up, climbing up the walls, and even flowing over the sides of a container.

Quantum Superconductors



A superconductor is a material which have zero electrical resistance and a perfect conductivity at very low temperatures. These materials expel all magnetic fields from its interior in a process called Meissner effect.

There are two particles of particular interest in this study.

Fermions

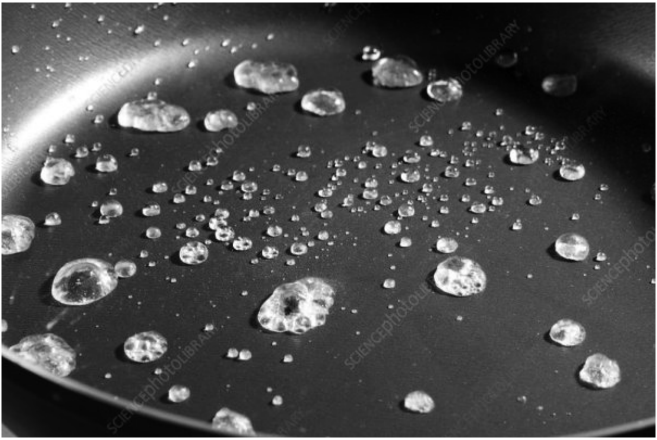
Fermions are particles which can't occupy the same place at the same time. These particles also can't share the superposition of the same state in this instant. The examples are electrons, neutrons and protons. They can overlap and when they do so, they won't be having the same state. This is the property which makes electrons bunch up near the nucleus and as they increase in number, they will be placed into orbitals of increasing energy piling on top of each other. This happens at the same time when the distance from the nucleus is also increasing. An orbital is simply an electron shell. As a result of this fermionic property, we have the atomic structure. And from atoms making chemical bonds, we can build anything in the universe including you.

Bosons

These are the particles which doesn't need to pile up because they can be in the same place superposition as their bodies, meaning they can also be in the same place at an instant. An example of a boson is the light photons. Remember you can overlap a lot of beams of light in the same place and this just increase their number instead of causing the bouncing of some particles from their path.

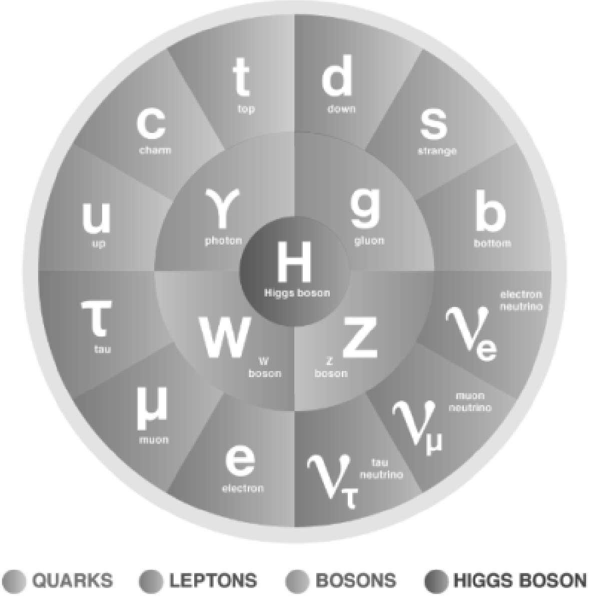
Now you can ask the question, what will happen is a gas is made up of bosons and is at a lower temperature. Basically you know by decreasing temperature, you will make a gas to lose some of its kinetic energies hence it will be drawn closer and closer to each other. This results in the gas condensing because the forces of attraction between the individual particles will increase at the particle come closer together. This gas with bosonic components will try and seek a rest state. Consider just like how rolling cylinders from each side of a U shaped ridge will end up at the middle. This is the same way which bosons come together forming super-fluids and superconductors.

Fried Water analogy



If a water droplet is out into a hot non-stick pan, it will bead up. It forms a bead of water that rolls around the surface without sticking. This is the same way as when a magnetic field hits the quantum superconductor. The quantum superconductor forms a bead which rolls around its surface without interacting with the material.

The Standard Model



This theory describes most information about the fundamental particles and forces. This theory is successful and has been tested numerous times in many experiments.

In chemistry we have the idea of the periodic table. This was established as a way to arrange particles in a particular order in order to make the study of different elements and their properties clearer.

To date it has 17 elementary particles, which includes leptons, quarks, and gauge bosons. Quarks are the fundamental blocks of neutrons and protons, while leptons include electrons, tau, and muons. Gauge bosons are particles that carry the fundamental forces in the universe, such as the photon (which carries the electromagnetic force), the W and Z bosons (which carry the weak force), and the gluon (which carries the strong force).

The Standard Model also describes the four fundamental forces which are gravity, electromagnetism, the weak force, and the strong force. The weakest force is gravity, but it then becomes the most important force as we consider large scales. Electromagnetism holds atoms together. The strong force is important and holds the nucleus of the atoms together. Lastly, the weak force is the one responsible for some radioactive decay.

Analogy of the Standard Model:

Imagine as if you are building any car. You will need to know some properties of the different parts needed for the car, for example the engine, the body, and the wheels. You will also need to know about how these parts interact and fit with each other. The Standard Model in physics is like the blueprint for a car being built. The model tells the properties of the fundamental particles and forces, the how they interact together.

QUANTUM COMPUTING

Classical computer uses classical bits but Quantum computers uses quantum bits (qubits). A classical bit can be either a 1 or 0 and it can never be these two at same time. But a qubit can be either a 1 or 0 and can also be in a superposition of 0 and 1 at the same time. This property allows quantum computing to perform operations which classical computer cannot do.

COMPONENTS

A quantum processor is made up of qubits and quantum gates. The quantum processor is the component which performs powerful computations Quantum memory is another component which stores information essential for quantum processor to function.

Quantum gates are building blocks to Quantum computing. They are similar to logic gates in classical computers but they can perform far more operations which are harder or even impossible for classical logic gates.

HADAM AND GATE (H GATE)

This is the quantum gate that changes a qubit from 0 or 1 to a superposition of 0 and 1. This property allows Quantum Computers to do what classical computers can't do.

CONTROLLED NOT GATE (C NOT GATE)

This gate allows two qubits to be linked making the state of one qubit control the state of the other qubit.

SHOR'S ALGORITHM

This is a quantum algorithm which is used to factor extremely large numbers used to factor extremely large numbers. Some number theory concepts cause a problem to classical computer such as factoring large numbers but this is easy for quantum computers due to **Shor's Algorithm.**

Shor's algorithm is then applied to many fields such as searching a database, breaking encryption schemes and solving optimization problems.

GROVER'S ALGORITHM

This quantum algorithm is used for searching unsorted databases. It was first proposed by Lov Grover in 1996. This process of searching is much faster than the searching in a classical computer. The algorithm works by performing a series of operations on a set of qubits which are initialized in a superposition state. This application includes very big data sets such as phone numbers, emails, house addresses and IP addresses.

BUSINESS APPLICATION OF GROVER'S ALGORITHM

It is used when optimization problems need to be solved such as when a sales man is travelling. They need find the shortest possible route to visit a set of cities. In this problem the algorithm is applied to quickly search for all the possible routes then by optimization give the shortest route.

CHALLENGES IN BUILDING A QUANTUM COMPUTER

It’s very difficult to safely store the qubits without them losing their quantum properties. This is called **QUANTUM DECOHERENCE** and it makes it difficult to build a practical quantum computer. Another problem lies in connecting the qubit so that they can communicate with each other. This is called quantum inter connectivity and hinders the system with a very big impact.

QUANTUM ERROR CORRECTION

This process involves detecting and correcting errors in qubits, which are likely to have the errors due to qubits, which are likely to have the errors due to **Decoherence.** This process requires a lot of computational power and a number of extra qubits and as a result makes it more difficult to build a practical quantum computer.

Application of Quantum Computers

Quantum Computers are useful in artificial intelligence, cybersecurity, quantum internet, complex systems and other fields. Quantum Computers have a potential use in training artificial intelligence models such as Neural Networks. This is much faster and could lead to so powerful AI models.

They could also be used in simulation of complex systems such as molecules and objects and this could bring new discoveries or even solve existing millennium problems such as the Navier-Stokes equations.

Quantum Computers are able to break the modern encryption methods such as the RSA while they can be used to create new, quantum resistant encryption technologies which will be more secured.

Lastly quantum computers could be used to develop a quantum internet and this would give much more secured information sharing platform.

Ethical and Societal implications off Quantum Computing

Quantum computers could be used for largescale surveillance and cyberattacks.

Glossary

1. Black body radiation – a body that emits all the electromagnetic radiation which it has absorbed.

1. Double slit experiment – an experiment when waves or particles with wave properties are passed through the slit and forms an interference pattern at the screen.

1. Electromagnetic force – force experienced by objects in magnetic or electric fields or light

1. Gravity – force that attracted objects with a mass

1. Grover's algorithm – an algorithm used to search databases

1. Hadam Gate – a gate that changes either a 0

or a 1 to a quantum superposition

1. Multiverse – the framework made from many worlds interpretation of quantum physics which believes in the existence of many universes

1. Photon – a packet of electromagnetic energy usually in a light sample

1. Probability – the likeliness of something to happen

1. Quantum computers – modern computer which uses quantum properties to operate

1. Quantum entanglement – process when two particles are linked despite being separated a very long distance

1. Quantum Gate – these are switches which uses quantum properties to work

1. Quantum hardware – the infrastructure built to support quantum systems for example quantum computers

1. Quantum immortality – a concept that people don’t surely die but their consciousness just shift to another universe

1. Quantum Superconductors – conductors made up of components in a quantum state and has zero resistance

1. Quantum Super-fluids – fluids made up of quantum particles and has zero viscosity

1. Quantum Superposition – process that allows a particle to have more than one state at the same time

1. Quantum Tunnelling – process that allows particles to penetrate regions where their

energies might not allow

1. Shor Gate – the gate used in the factoring of extremely big numbers

1. Standard Model – this is the most accurate description for particles and forces found in the universe

1. Strong force – force binding quarks together

1. Ultraviolet Catastrophe – this was a scenario when the experimental observation on the blackbody radiation didn't match the theory

1. Wave-functions – this is a mathematical function which describes quantum particles and their properties

1. Weak force – force responsible for beta decay

QUANTUM
MECHANICS
VALENTINE SHEREKETE

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About the Author

Valentine is a high school student who have been enthusiastic about Quantum Physics thus he embarked on this journey. At first it was difficult for him but his drive towards finding the true nature of the universe led him to love the subject. Eversince he has tried to share the knowledge with as many people as possible.